Analytical Abstracts of Current Literature.

Summary of Current Pre-Cambrian North American Literature.

Prefatory Note.—The summary of current pre-Cambrian literature beginning in this number, which will continue in following numbers, though probably not consecutively, is made upon somewhat different principles from those ordinarily used. The fundamental ideas of the plan are as follows: The summary proper and the comments are kept wholly separate, in this way preventing the confusion which frequently comes from a mingling of the two. In the summaries the original language of the author is used as far as practicable, although a single sentence may be taken from several sentences of the original. Where it is disadvantageous to use the original language other words are used. This often is necessary, because the language which is adapted to complete exposition is often not the best adapted to résumé. No quotations are made; for the ideas contained, whether in the original language or not, are wholly the ideas of the author, the whole is in fact really quoted. It might be thought that better results would be reached by indicating through quotations what words are taken from the original, but this method would necessitate an unpleasant and constant alternation from quoted to non-quoted phrases. As a result of experience with the two methods, the editor feels certain that he is able more accurately and fully, in a brief space, to represent the ideas of the original author by the method proposed, than by following the usual method.

The summaries are confined to articles or parts of articles pertaining to pre-Cambrian stratigraphy. Purely economic or petrological articles are not summarized unless they concern pre-Cambrian stratigraphy, in which case the substance of the conclusions are given, rather than a full account of the observations and the manner of reaching them. The abstracts have the defects of all summaries,—a certain amount of inaccuracy, because many modifying and qualifying facts can not be given, and because undue emphasis is placed upon the conclusions.

In many cases no comments are made. This does not imply that the editor agrees with the statements of the summaries. To criticize, qualify, or refute the statements of the authors in all cases of disagreement, would often

result in extending the space taken by the comments beyond that required for the summaries. However, when the points at issue are of general interest, or fundamental importance, it is advisable to make comments and enter into discussions, even if the space taken by such comments be greater than that given to the summary of the original articles. In such comments neither commendation nor censure will be made, but the aim will be to point out the conclusions announced which fail of complete establishment, and the generalizations which appear to go beyond what is warranted by the facts published. The purpose of indicating what appears to the editor as deficiencies of these kinds is neither to put himself dogmatically in opposition to the statements of the author reviewed, nor with the belief that his opinion has more weight, but to direct attention to the questions involved, and in cases of doubt to keep them open for farther study in the field and laboratory.

Mills[1] finds in the Sierra Nevada, unconformably below the Mesozoic, eruptive granites and sedimentary slates and quartzites. The latter in places rest and were probably deposited upon the granite, while in other places they are contemporaneous and imbedded within it. The quartzites are held to be silicified phases of the slates. These rocks in age may run from Archæan to the Paleozoic and some of them may be early Mesozoic.

Darton[2] finds Ordovician fossils in the crystalline slates and schists of the Piedmont plain of Virginia, these rocks having been previously regarded as Huronian.

Lesley[3] gives a summary sketch of the pre-Cambrian rocks of Pennsylvania, the facts being taken from the detailed state reports. The Highland Belt of New Jersey and Pennsylvania; the Reading and Durham Hills; areas in Chester, Bucks, Montgomery and Delaware counties; and an area on the Schuylkill river are placed in the Archean. All are regarded as sedimentary in origin, because of the presence of marble, apatite and iron ore. The newer gneiss of the Philadelphia belt, the Azoic formations of York, Chester and Lancaster counties, and the South Mountain rocks are not definitely referred to any system. The term Huronian must be used simply as a proper and private name for a series of rocks exposed along a part of the northern boundary of the United States. Should a similar series appear in some other region and be called Huronian on account of the resemblance, the name would have no value whatever; unless we should imagine that in a so-called Huronian age the whole surface of the planet was stuccoed with a certain formation; and

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[1] *Stratigraphy and Succession of the Rocks of the Sierra Nevada of California.* James E. Mills. Bull. Geol. Soc. of America, vol. 3, 1892, pp. 413–444.

[2] *Fossils in the "Archæan" rocks of Central Piedmont Virginia.* N. H. Darton. Am. Jour. Sci., 3rd series, vol. 44, 1892, pp. 50–52.

[3] *The Laurentian and Huronian Formations*, by J. P. Lesley, in A Summary Description of the Geology of Pennsylvania, Vol. I. Rep. Penn. Geol. Sur., 1892, pp. 53–164.

received successive coats of other kinds of rock in after ages. The most dissimilar series of formations are known to be of the same age. What is happening to-day has happened in all ages. Nothing could be more unlike than the deposits now forming along the various ocean shores, and in different lakes and inland seas; yet they are all of one age. Even the deposits making in one and the same basin radically differ; as, for example, along the northern and southern sides of Lake Ontario; and along the eastern and western sides of Lake Champlain. It would therefore seem a useless task to seek for the Huronian rocks far from their native range.

Nason[1] fully describes the iron ores of the porphyry region of Missouri, and incidentally treats of the associated rocks. The porphyries usually show evidence of bedding, but this may be that of igneous flows. The Cambrian limestones and sandstones flank and rest unconformably upon the granites and porphyries. The iron ore of Iron Mountain and most of the other localities is in veins in the massive rock, probably of water infiltrated origin; or in a residuary mantle; or as concentrated detritus along the slopes or ravines of the porphyries. In the two latter cases the ore is derived from the veins. In some cases this concentration occurred before or during the deposition of the Cambrian sandstones and limestones, but in other cases is subsequent to the deposition of these rocks. At Pilot Knob the succession from the base upward is porphyry; conglomerate; a slaty ripple marked stratum in contact with the ore body; main ore body, nineteen to twenty-nine feet thick; highly ferruginous slate, one to three feet thick; heavy beds of conglomerate with an average thickness of one hundred feet. The pebbles of the conglomerate are mainly derived from the porphyries, but the regularly laminated slate and ore have a thin bedded structure, which is such as to lead to the conclusion that they are undoubtedly of sedimentary origin.

Bell[2] gives a general account of the Laurentian and Huronian systems, and a sketch of the geology of the country extending from Lake Huron northward to Lake Temiscaming, and from Lake Nipissing westward to the Spanish river. The Laurentian system is divided into an upper and a lower formation. The latter consists almost entirely of fundamental gneiss, while the upper Laurentian appears to consist of metamorphosed and sedimentary strata, to some extent at least.

The lower division of the Laurentian consists of red and gray gneiss, usually much bent or disturbed, and having generally a rudely foliated structure, and a solid or massive character. The feldspar is almost entirely ortho-

[1] *The Iron Ores of Missouri*, by Frank L. Nason. In Rep. Geol. Sur., Missouri, for 1891–2, Vol. 2, pp. 16–69. Jefferson City, 1892.

[2] *The Laurentian and Huronian Systems North of Lake Huron, accompanied by Geoolgical Map.* Dr. Robert Bell, Rep. of Bureau of Mines, Ontario, 1891, pp. 63–94. Toronto, 1892.

clase. The upper division of the Laurentian is more complex. It possesses more regularity in stratification and includes great banded masses of crystalline limestones, vitreous quartzites, mica-schist and hornblende-schist, massive pyroxene, and massive and foliated labradorite rocks. Considerable areas of granite and syenite occur in the formation. The Upper Laurentian of the Ottawa valley may be roughly estimated to be at from 50,000 to 100,000 feet in thickness.

While the older Laurentian rocks afford no proof of the permanent existence of the sea upon the earth, water appears to have been present, perhaps only as precipitations upon the surface, at every stage of its formation. But the deposits of limestone and tolerably pure silica in distinct bands in the Upper Laurentian afford strong support to the aqueous theory of its deposition.

With the beginning of the Huronian period great volcanic activity began, and there is evidence of the permanent abode of water on the surface of the earth. The general character of the Huronian rocks may be said to be pyroclastic, by this signifying that, although fragmental, they have nevertheless had an igneous origin.

The area mapped between the Huronian belt and the shore of Georgian bay appears to belong to the Upper Laurentian. The rocks are gneisses of the typical Laurentian varieties, finely stratified and regularly arranged in anticlinal and synclinal folds, the angles of dip usually not being far from forty-five degrees, but lesser and greater dips being found. Red and gray varieties are about in equal proportion, and they alternate with each other in thick and thin sheets. Mica-gneisses are predominant. No beds of crystalline limestone are found west of Iron Island in Lake Nipissing. Limestones are associated with the gneisses on some of the islands of the eastern part of this lake and at Lake Talon on the Mattawa. In the Parry Sound district are five distinct bands of Laurentian limestone. These rocks are classified with the Upper Laurentian rocks of the counties of Ottawa and Argenteuil.

The Laurentian rocks northwest of the Huronian belt are heavy contorted gneisses of the lower Laurentian. Associated with the gneisses are red granites which are classed with the Laurentian, but which may be really Huronian. These may have formed by softening the gneiss by heat, combined with re-crystallization, or they may be due to the alteration of the Huronian arkoses or graywackes, or they may be mainly eruptive. These granites are along the contact line between the Laurentian and Huronian. Along the line of contact between the granites and Huronian quartzites and schists, the rocks are much broken. It is not improbable that a fault exists at the line of junction between the Laurentian and Huronian rocks.

The great Huronian belt consists of a great variety of rocks, such as crystalline schists, quartzites, conglomerates, agglomerates, clay-slates, greenstones, dolomites, etc., the majority of which are pyroclastic. The rocks are

usually tilted at high angles. There are numerous instances where there is a gradual transition from the Huronion to the lower series. A few instances of local want of conformity between the two is no evidence that the two systems are not conformable on a grand scale. The few known instances where there appears to be a want of parallelism are more probably due to faulting. The pyroclastic rocks show the agency of water in their formation, and were largely derived from igneous matter, which had been more or less recently erupted. The newest rock of the Sudbury district is a volcanic breccia, which forms a continuous range of hills for a distance of thirty-six miles, with a breadth in the center of eight miles. Within the Huronian rocks are intrusive red granites.

Comments. Attention is called to the implication that the unconformity at the base of the Huronian, if it exist at all, is of a local character. The very idea of an unconformity pre-supposes that it can not be local in the narrow sense. A minor unconformity even marks a considerable time break, and when an earlier series has been profoundly metamorphosed and deeply denuded before the overlying series is deposited upon it, the break must be of regional extent, even if the contacts found are few and of small extent. It, however, does not follow that the break is universal nor even that it always extends throughout a geological basin. Space does not permit a discussion of the evidence for the existence of unconformable contacts at the base of the original Huronian in certain localities. It is enough to say that Irving, Pumpelly, Reusch, Barrois, and Tschernychew, all having seen one of the localities and the first two both, agree that the only interpretation of the phenomena at points near Garden river and near Thessalon is that of a great unconformity, not faulting as suggested by Bell, who does not appear to have ever visited these localities.

Barlow [1] states that the Huronian system is the oldest sedimentary strata of the north shore of Lake Huron, and that the Laurentian gneiss or Basement Complex is the original crust of the earth or floor on which the first sediments were laid down. This floor, as shown by the pebbles of the Huronian, was granite which had in many places a foliated or gneissic structure. In many places the subsequent folding and fracturing of the comparatively thin crust of the earth has caused large portions of the Huronian to sink below the plane of fusion, the result of which has been to produce irruptive contacts. At other places, as described by Pumpelly and Van Hise, the Basement Complex may have remained undisturbed so that the overlying detritals have not been intruded by the granitic mass beneath.

Hall and Sardeson [2] describe the Upper Cambrian rocks of Southeastern

[1] *On the relations of the Laurentian and Huronian on the North Side of Lake Huron.* Alfred E. Barlow. Am. Jour. Sci., 3d series, vol. 44, 1892, pp. 236–239.

[2] *Paleozoic Formations of Southeastern Minnesota.* C. W. Hall and F. W. Sardeson. Bulletin Geol. Soc. of America, vol. 3, 1892, pp. 331–368.

Minnesota as resting unconformably upon a pre-Paleozoic floor. The base of the Potsdam is usually conglomeratic. At Minneopa a well 800 feet deep passed through a conglomerate for a distance of 225 feet, the pebbles of which are vitreous quartzite like those occurring in Cortland, Watonwan and Cottonwood counties. A conglomerate containing granitic debris is found on Snake river about two miles above Mora, and three miles distant from the Ann River knobs of hornblende-biotite-granite, the clastic appearing to be derived from the granite. At Taylors' Falls a conglomerate made up of pebbles of diabase rests upon the diabase of the St. Croix river. These underlying formations are Archean and Algonkian rocks.

Grant [1] states that the Animikie rests unconformably upon the Saganaga granite; that the Ogishki conglomerate is intruded by the Saganaga granite, and therefore that the Ogishki conglomerate is earlier than and separated by a great structural break from the Saganaga granite. As the Keewatin has the same relations to the Saganaga granite as the Ogishki conglomerate, the same thing is true of the Animikie and Keewatin. The Ogishki conglomerate is younger than the most of the Keewatin, but is considered as a part of it.

Comments :— The most characteristic and abundant fragments in the Ogishki conglomerate are granite. The rock occurs in pieces running from those of minute size to great bowlders. It is manifest that this material was derived from a pre-existing granite. These bowlders are in all respects like much of the Saganaga granite, and the probability is very strong that this is their source. Grant is probably correct as to the intrusion of the conglomerate by a granite, but this granite may have also intruded the main Saganaga mass. The too frequent mistake has apparently been made of concluding that in the Saganaga area there is granite of but one age, when frequently in the great massives of the Northwest, granites of several ages occur, the latest ones cutting all the previous ones, and often the far newer clastics. It further follows that the implication that the Animikie is unconformably upon the Ogishki conglomerate needs the support of additional evidence. That this conglomerate is possibly more nearly related to the Animikie than to the Keewatin is shown by the presence of abundant jasper fragments, presumably derived from the Keewatin. The article appears to be another illustration of the facts being right, the author in his interpretation, however, overlooking a part of the facts which are to be accounted for in making a true generalization.

Winchell [2] gives a review of the literature on the Norian of the Northwest. Here are included the gabbros, placed as the basement member of the

[1] *The Stratigraphic Position of the Ogishke Conglomerate of Northeastern Minnesota*, U. S. Grant. Am. Geologist, vol. 10, 1892, pp. 4–10.

[2] *The Norian of the Northwest*, by N. H. Winchell. In Bull. 8, Geol. and Nat. Hist. Sur., Minn. 1893, pp. iii–xxii.

Keweenawan by Irving, and the Bohemian Mountains of Keweenaw Point. It is suggested that the anorthosites of Lawson are but facies of the gabbro, and that the two belong together in the Norian.

Comments : — This paper correlates with the so-called Norian of the East the gabbros and similar rocks of the Lake Superior region, which have heretofore been considered as constituting a part of the Keweenawan. Such lithological correlations are believed to retard, rather than advance geological progress, as they rest wholly upon unverified assumptions. The local name Keweenawan ought to be retained for the gabbros and allied rocks, or else some new local name ought to be devised for it. This latter is done by Lawson as appears from the paper next summarized.

Lawson[1] gives a petrographical and structural account of the anorthosites of the Northwest shore of Lake Superior. The anorthosite is wholly massive, completely granitic in structure, and is composed almost wholly of basic feldspar, varying in composition from labradorite to anorthite. The rock occurs near Encampment Island, in the vicinity of Split Rock point, at Beaver Bay and vicinity, at Baptism river, on the slopes of Saw Teeth mountain, and at Carlton Peak. In nearly all of these localities the rock is found in rounded dome shaped masses below the other eruptives of the coast. It is cut by these different eruptives, and in the lava flows are found very numerous blocks and bowlders of anorthosite, which were caught in at the time of their extrusion. These facts show that the anorthosite is of pre-Keweenian age, and since the anorthosite is a plutonic rock, it must have suffered profound erosion prior to the extravasation of the Keweenian eruptives. Norwood, Irving and Winchell have described the blocks of anorthosite in the lavas at some of the points. Winchell regarded the anorthosite at Split Rock as older than the eruptives containing masses of them, and Irving reached the same conclusion in reference to the anorthosite at Carlton Peak. However, none of them differentiated the anorthosite mass from the general aggregation of volcanic flows, constituting the Keweenian series of the Minnesota coast. The surface of the pre-Keweenian anorthosite is domed and hummocky like that of the other Archean terrains of Canada, and it is thought to have been only modified by Pleistocene erosion. The interval between the anorthosite and the Keweenian is probably the same as the pre-Paleozoic interval which effected the reduction of the Archean to the great hummocky plain, to which it was reduced before the Animikie was deposited upon it. As the Keweenian rests directly upon the anorthosite, the Animikie is absent for the middle third of the Minnesota coast. Irving places the thickness of the Keweenian of the area at 20,000 feet, stating that it may reach 22,000 or 24,000 feet. The maximum thickness of the

[1] *Anorthosites of the Minnesota Shore of Lake Superior*, by A. C. Lawson. In Bulletin 8, Geol. and Nat. Hist. Sur., Minn., 1893, pp. 1–23.

Keweenian is not more than one-tenth of this thickness. Irving's subdivision of the Keweenian into groups, and his estimate of the thickness of various portions of the series are of little value; a statement which it is as painful to make as it is necessary in the interests of sound geology. The anorthosite is provisionally correlated with the Norian of the Province of Quebec, but as this correlation is merely a hypothesis, the name Carltonian is suggested for this formation.

Comments :—The main structural conclusion of Lawson, that the anorthosite of the Northwest shore of Lake Superior is older than and was deeply eroded before the deposition of the upper Keweenawan lava flows, seems clearly established, and this is a conclusion of great importance. However the general inferences which are drawn from this relation call for more evidence.

At the outset it is to be noted that the term Paleozoic is extended to include the Keweenian and Animikie series, a usage not followed by many and involving a great proposition which demands evidence. The question is, however, too large to discuss here.

The Keweenaw series of Northeastern Minnesota is of great extent and thickness. Irving, in his latest paper on the pre-Cambrian divided the Keweenawan into two divisions, a lower basal gabbro, and an upper series, consisting of thinly-bedded basic and acid rocks.[1] The anorthosite is but a facies of gabbro, in which the pyroxenic constituent is reduced to a minimum. The most probable explanation of the relations made out by Lawson, as it appears to me, is that the anorthosite exposed on the coast belongs with this great basal gabbro, and this is the position which is apparently favored by Professor Winchell,[2] although he regards the whole gabbro mass as pre-Keweenawan. This latter is a matter of definition, and is contrary to the general usage of the term in the past, both divisions having been generally regarded as making up the Keweenawan. The length of the period represented by the Keweenawan was so great, that after the outflow or intrusion of the basal gabbro there may have been along the Minnesota coast a period of erosion, thus cutting deep into the gabbro, anorthosite and associated rocks. Later in Keweenawan time this eroded surface was covered by the flows of the upper division. Indeed this unconformity between the basal gabbro of the Keweenawan and the upper, more thinly-bedded members of the series was noted by Irving[3] both for the Bad River area of Wisconsin and for Minnesota, and is

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[1] *The Classification of Early Cambrian and pre-Cambrian formations*, by R. D. Irving. In 10th Annual Rep. U. S. G. S., pp. 418–420.

[2] *The Norian of the Northwest*, by N. H. Winchell. In Bull. Nat. Hist. and Geol. Sur., Minn., pp. 28, 19.

[3] *Copper Bearing Rocks of Lake Superior*, by R. D. Irving. In Third Annual Rep. of Director U. S. G. S., pp. 134, 136, 137. Also Mon. 5, U. S. G. S., pp. 155, 156, 158, 159.

reinforced in the latter case by his map of Northwestern Minnesota, which suggests that the upper division of the Keweenawan overlaps the lower unconconformably.

In the first of these areas the thin-bedded flows are described as being poured out against the gabbro mass, which, it is said, must have stood to a great height, until finally the flows accumulated sufficiently to cap the upper surface of the gabbro. So strongly was Irving impressed by these facts, that he states that he was inclined at first to place the gabbros of the Bad River district with the Huronian, and to regard them as the equivalents of the great flows of the Animikie series of Thunder Bay, but, finding the Animikie slates unconformably under the gabbros, he preferred to put them as the earliest division of the Keweenawan, clearly recognizing that there was a very considerable unconformity between these coarse, massive rocks and the later thinly-bedded ones. This reference was made because of the close lithological relationship of the gabbro and the Keweenawan diabases, and because in eruptive series such breaks were regarded as less significant.

It thus appears that Irving fully appreciated an unconformity, probably at the horizon of Lawson's unconformity, but he did not recognize that the break which has so extensive an occurrence also exists along the Minnesota coast. If the explanation suggested as to the relations on the Minnesota coast be true, Irving's statements, used in reference to the Bad River area, can be applied almost exactly to this one, in which case the difference between Irving and Lawson is that of nomenclature. Lawson restricts the term Keweenawan to the upper part of the series, whereas Irving and other writers regarded the Keweenawan as including both divisions. It also follows, if the anorthosite is Keweenawan, that Lawson's conclusion that the Animikie is absent below the Keweenawan in Northeastern Minnesota, is without foundation, for the base of the Keweenawan thus defined is not here exposed. Further, the Animikie is certainly unconformably below the great basal gabbro of Minnesota. It further follows that the correlation of the anorthosites of Lake Superior and those of the Province of Quebec has no value. But, wholly apart from the stratigraphy of Northeastern Minnesota, I must confess to a complete lack of confidence in the correlation of eruptive rocks so far removed as these.

To the statement that Irving's subdivision of the Keweenawan into groups and his estimate of the thicknesses of various portions of the series are of little value, I feel that I must take exception. The painstaking character of all of Irving's work is well-known. He spent many years of study upon the series in Michigan and Wisconsin. His study, and that of his assistants, Messrs. Chauvenet, Cambell and McKinley, on the northwest coast of Lake Superior was of a detailed character. It would seem scarcely possible that Dr. Lawson's study of the stratigraphy in a single trip, in which he made no attempt to re-measure the sections (so far, at least, as can be ascertained from his paper) could have been detailed enough to warrant this sweeping state-

ment. On one point Irving seems not to have fully drawn the conclusion which legitimately followed from his observations. This, however, does not invalidate the observations in any way, nor lessen the strength of the many important conclusions which were reached. The only particularized notice by Dr. Lawson of these supposed errors is in reference to the thickness of the Keweenawan. The statement that Irving overestimated this thickness tenfold certainly needs additional justification. The thicknesses given are maxima for the particular region. Irving was perfectly well aware that the Keweenaw series varies greatly in thickness from place to place, being largely of volcanic origin. He also knew that it varies from its maximum thickness to entire disappearance at a not very remote distance from the Lake Superior basin. That a volcanic series is not of great thickness in one particular area of a region is no evidence that it is not so in other parts. If the anorthosite division of the Keweenawan constituted a mountainous mass for the central part of the Minnesota coast, and the upper Keweenawan beds were deposited against them, as before suggested, these later beds may have a very great thickness remote from the anorthosites, or at the inaccessible base of the past mountain range, and this would be quite in accordance with a moderate thickness near the tops of the anorthosite domes.

Lawson[1] describes the laccolitic sills of the northwest coast of Lake Superior. The trap sills are mainly diabases, but they occasionally pass into gabbros. It is held that there are no contemporaneous volcanic rocks in the Animikie group, and that the trap sheets are intrusive in their origin, rather than subsequent volcanic flows, for the following reasons: They are simple geological units, one not overlapping another; they have a uniform thickness over areas more than 100 square miles in extent; where inclined, the dip is due to faulting and tilting; they have no pyroclastic rocks associated with them; they are not glassy nor amygdaloidal; they show no flow structure, or other distinct properties of effusive rocks; their contacts with the slates are sharp; they never repose upon a surface which has been exposed to weathering or erosion; they are analogous to the great dikes of the region in all their relations; they may be observed in direct continuity with dikes; they pass from one horizon to another; they have a columnar structure extending throughout their thickness; apophyses pass from the main sheets into cracks of the slate above and below; they locally alter the slates above and below them.

The Animikie strata have been dislocated by a great system of faults, the orographic blocks having been frequently tilted. The non-recognition of this prevalent tilted structure has led to very excessive estimates of the thickness of the series by Irving and Ingalls. In the vicinity of Black Sturgeon River

[1] *The Laccolitic Sills of the Northwest Coast of Lake Superior*, by A. C. Lawson. In Bull. 8, Geol. and Nat. Hist. Sur., Minn., pp. 24–48.

and on the Isles of Nipigon Bay are numerous places where Keweenian strata are capped by thick sheets of trap, identical with those which cap the Animikie, but, though these sheets cannot be traced in absolute continuity in the interval, there are many outlying patches which fill the gap. The same trap sheets are found in several instances to pass from the Animikie to the Keweenian, and there are the same evidences of intrusion of independent trap sheets in the Keweenian that are in the Animikie. These rocks are, therefore, of post-Keweenian age, and, to discriminate them from the Keweenian and Animikie, they are designated the Logan sills.

Comments :— The fact that all the trap sheets of the Animikie studied by Lawson are intrusive is no evidence that in other areas, not studied by him, there may not be contemporaneous volcanics. The traps in the Triassic of Connecticut and New Jersey are an illustration of this point, a part of them being extrusive and a part intrusive. Also in the Penokee series, the equivalent to the Animikie series, while for the main part of the area there are no contemporaneous volcanics, in the eastern end of the series there suddenly appears a great thickness of contemporaneous volcanic fragmentals, and such may occur in the Animikie in the areas not yet studied.

The inclination of the Animikie series was fully recognized by Irving and Ingall, and this it was which led them to make their estimates of the thickness. The statement, that the strata have been dislocated by a great system of faults, may be true, but in the paper it is not supported by any evidence; and, until detailed evidence is presented, the conclusion of Irving and Ingall as to the thickness seems more probably true than the hypothesis of numerous faults.

Because the sills are later than the Animikie and Keweenawan strata which they have intruded, is no sufficient evidence that they are post-Keweenawan. The thickness of the Keweenaw series is so great that it is quite reasonable to expect that correlative with the later extrusions were intrusions between the older Keweenawan strata. To explain all the facts cited on the northwest coast it is only necessary to suppose that the upper part of the Keweenawan has been removed by erosion, and that the sills now composing the upper layers in these places were overlain at one time by higher members, which have subsequently been removed by erosion. This is not a violent supposititon, for it is well known that erosion and volcanic extrusion alternated many times in single areas during Keweenawan time.

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